Network Systems Science & Advanced Computing

Biocomplexity Institute & Initiative

University of Virginia

Estimation of COVID-19 Impact in Virginia

September 2nd, 2020

(data current to September 1st)

Biocomplexity Institute Technical report: TR 2020-107

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About Us

- Biocomplexity Institute at the University of Virginia
  - Using big data and simulations to understand massively interactive systems and solve societal problems
- Over 20 years of crafting and analyzing infectious disease models
  - Pandemic response for Influenza, Ebola, Zika, and others

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Overview

- **Goal**: Understand impact of COVID-19 mitigations in Virginia
- **Approach:**
  - Calibrate explanatory mechanistic model to observed cases
  - Project infections through October
  - Consider a range of possible mitigation effects in "what-if" scenarios
- **Outcomes:**
  - Ill, Confirmed, Hospitalized, ICU, Ventilated, Death
  - Geographic spread over time, case counts, healthcare burdens

Key Takeaways

Projecting future cases precisely is impossible and unnecessary.
Even without perfect projections, we can confidently draw conclusions:

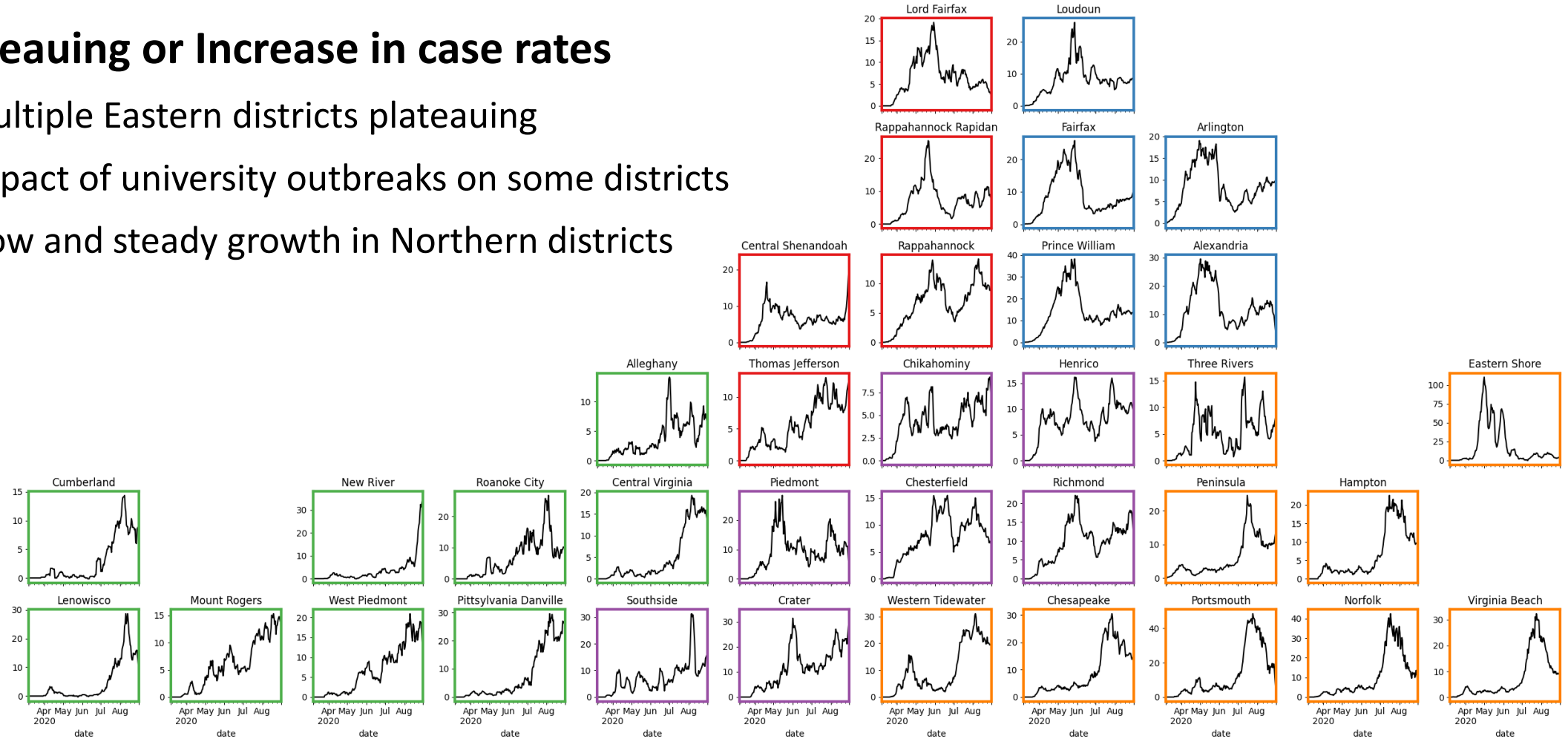
- **Mixed trends remain: surges fade as others begin, growth plateaued overall, with high variation across the state. Incidence hovers at national average.**
- Projections are also mixed across a range of slow-growth, plateaus, and declines.
- Recent model updates: Recent model updates:
  - Adaptive Fitting projection remains, slight adjustments to projection filtering.
  - Seasonal effects scenarios for planning for end of summer changes.
- The situation is changing rapidly. Models will be updated regularly.

Situation Assessment

Case Rate (per 100k) by VDH District

Plateauing or Increase in case rates

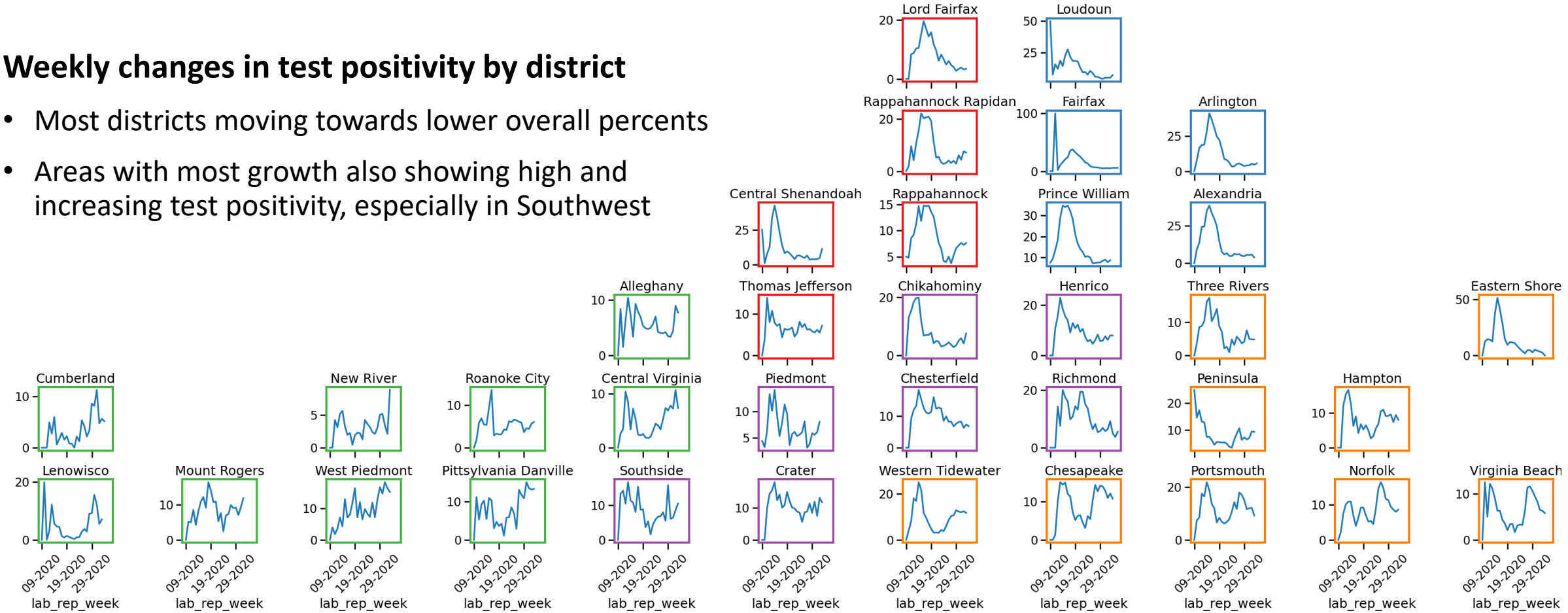
- Multiple Eastern districts plateauing
- Impact of university outbreaks on some districts
- Slow and steady growth in Northern districts



Test Positivity by VDH District

Weekly changes in test positivity by district

- Most districts moving towards lower overall percents
- Areas with most growth also showing high and increasing test positivity, especially in Southwest



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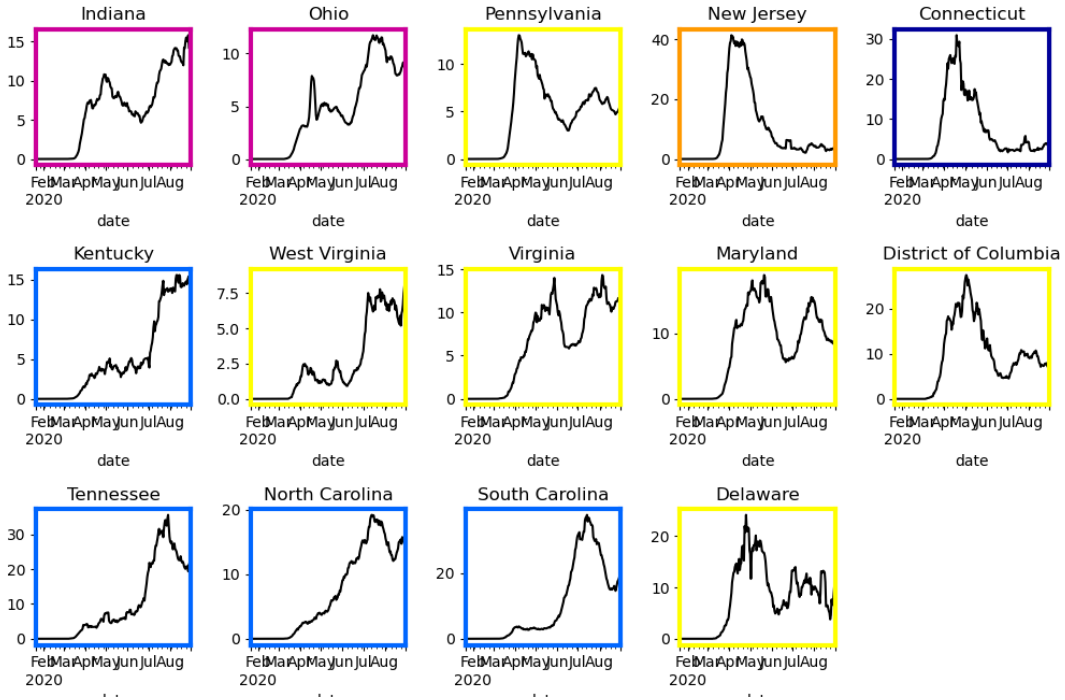
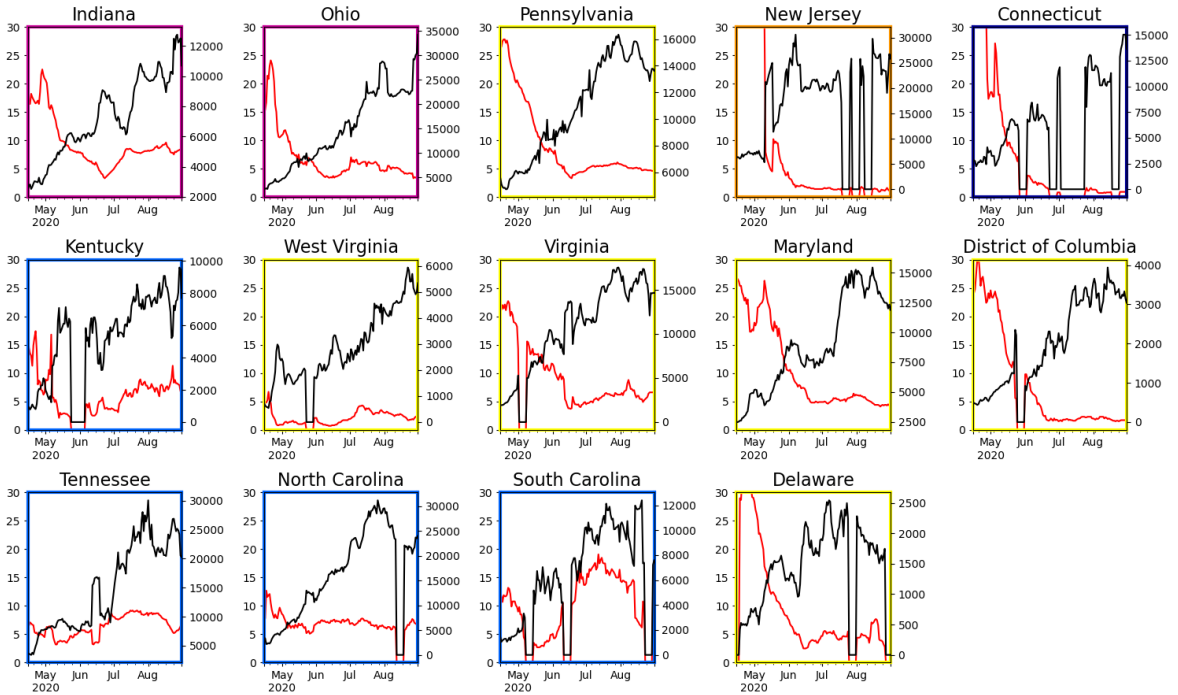
Other State Comparisons

Case Rate per 100K population



Tests per Day and Test Positivity



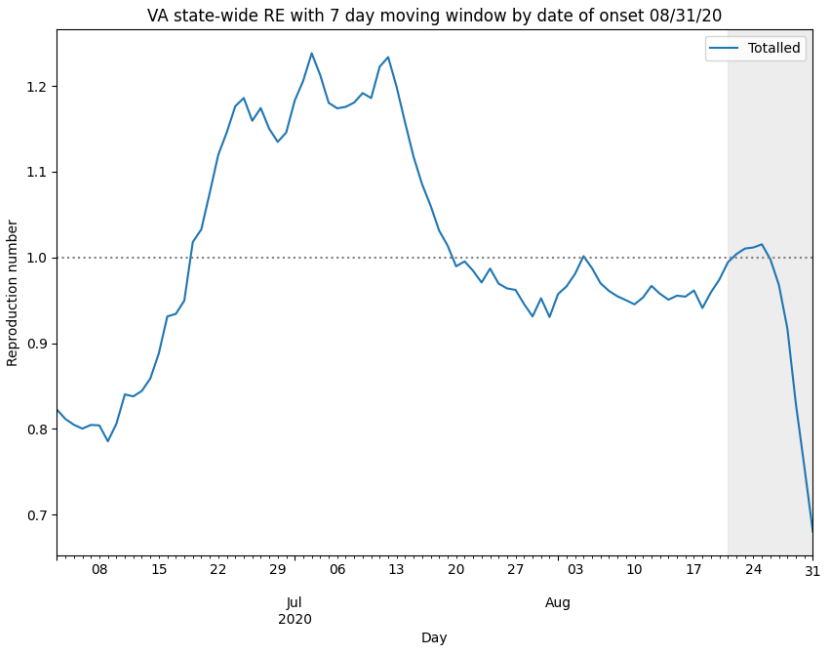
- Most states experiencing declines or plateaus in last weeks
- SC and NC showing some rebounds
- KY and WV plateauing, and TN declining but still quite high

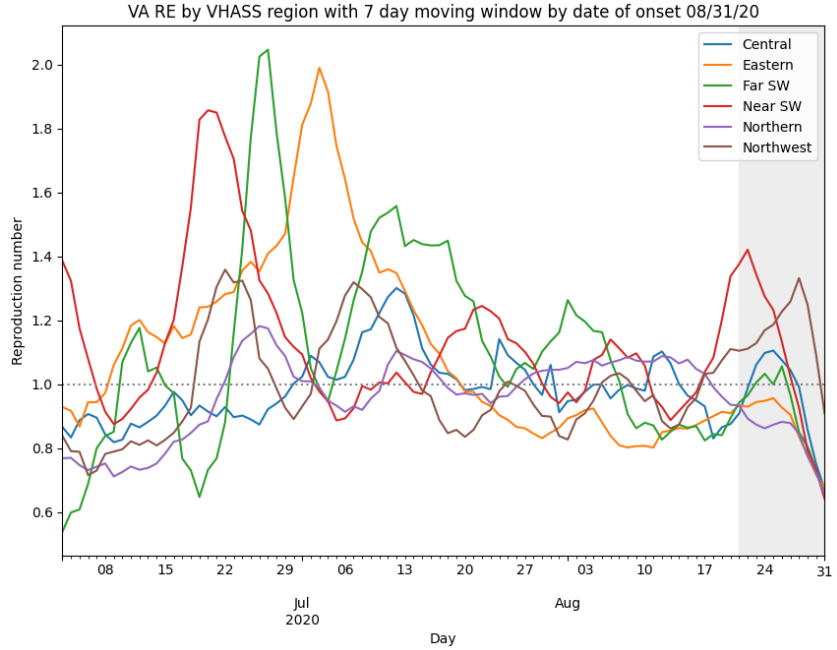
- Good signs as test positivity shows recent decline in most states
- Testing volumes steady or growing in most states

Estimating Daily Reproductive Number

August 22nd Estimates

Region	Current R_e	Diff Last Week
State-wide	1.004	0.078
Central	0.987	0.070
Eastern	0.929	0.082
Far SW	0.965	0.127
Near SW	1.421	0.441
Northern	0.893	-0.126
Northwest	1.111	0.226





Methodology

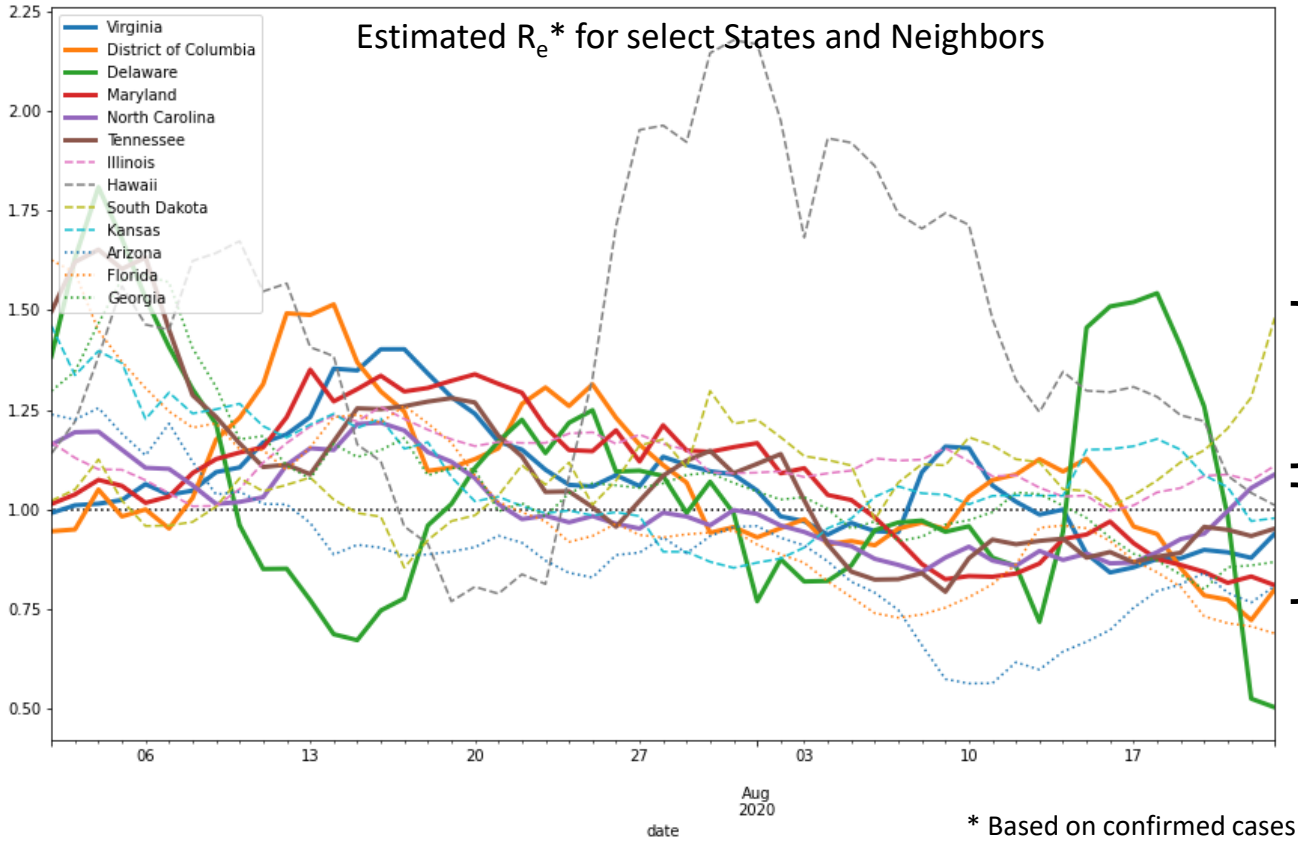
- Wallinga-Teunis method (EpiEstim[1]) for cases by date of onset
- Serial interval: 6 days (2 day std dev)
- Recent estimates may be unstable due to backfill

1. Anne Cori, Neil M. Ferguson, Christophe Fraser, Simon Cauchemez. A New Framework and Software to Estimate Time-Varying Reproduction Numbers During Epidemics. American Journal of Epidemiology, Volume 178, Issue 9, 1 November 2013, Pages 1505–1512, https://doi.org/10.1093/aje/kwt133

Other State Comparisons

Reproductive Number (R_e) has downward trend across hotspots and Virginia's neighbors

- New states in Mid-west and Plains emerging as hot spots, IL, KS, SD as well as HI
- Virginia and neighboring states are mostly at and below 1



New states in emerging as hot spots

VA and neighbors continued decline

* Based on confirmed cases per day

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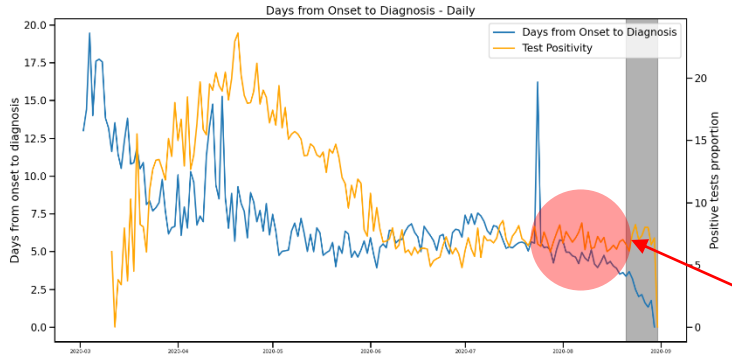
Changes in Case Detection

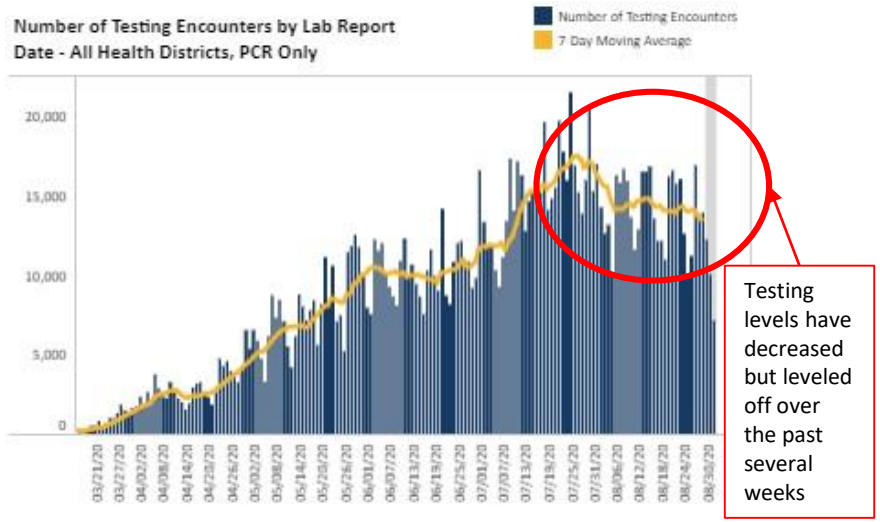
Timeframe (weeks)	Mean days	% difference from overall mean
April (13-16)	8.51	35.22%
May (17-21)	5.7	-9.40%
June (22-25)	5.78	-10.08%
July (26-30)	6.22	-1.20%
Aug (31-32)	4.55	-27.65%
Overall (13-32)	6.29	0%

Test positivity vs. Onset to Diagnosis

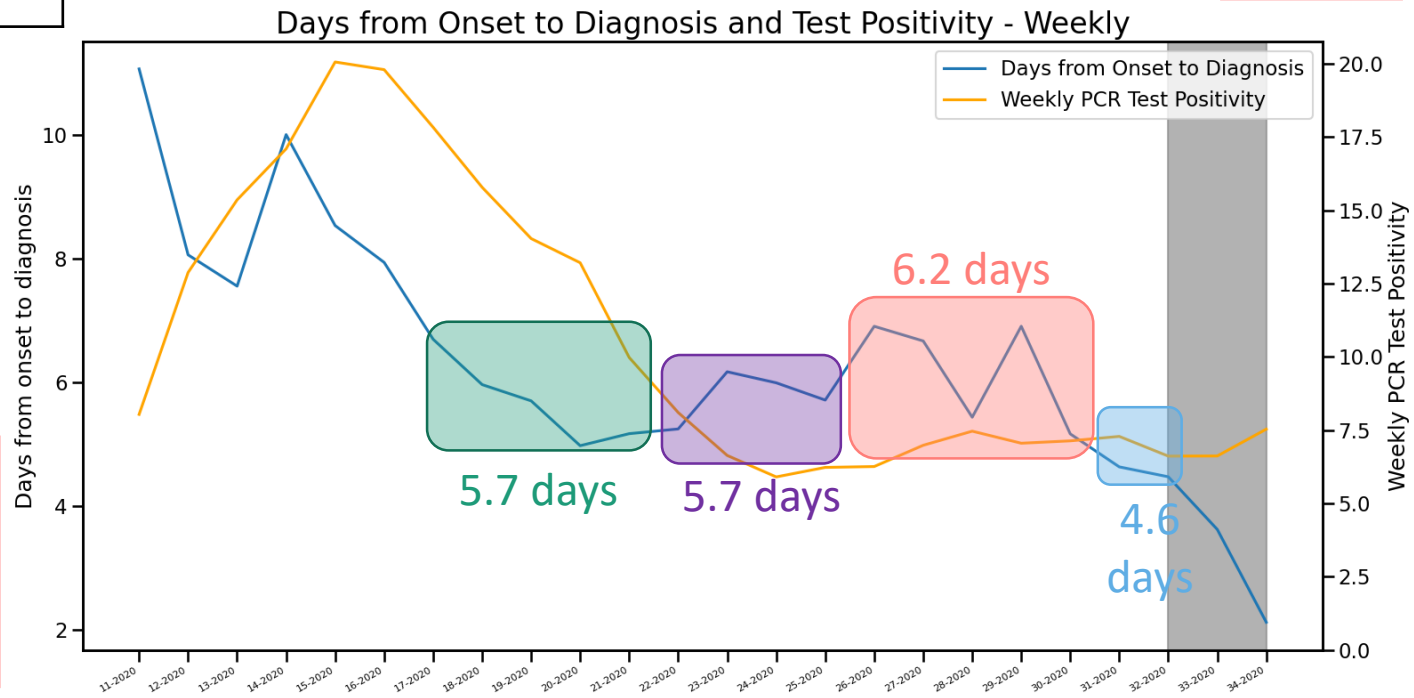


Steady plateau has been maintained for past several weeks

Testing Encounters and test positivity have steadied and increased

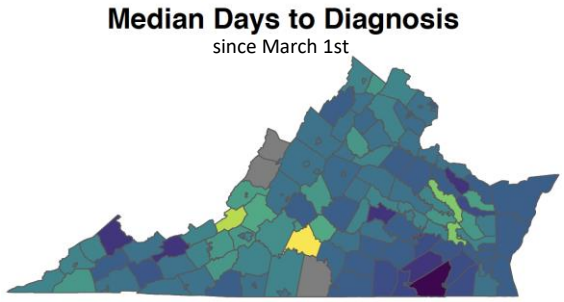


Testing levels have decreased but leveled off over the past several weeks

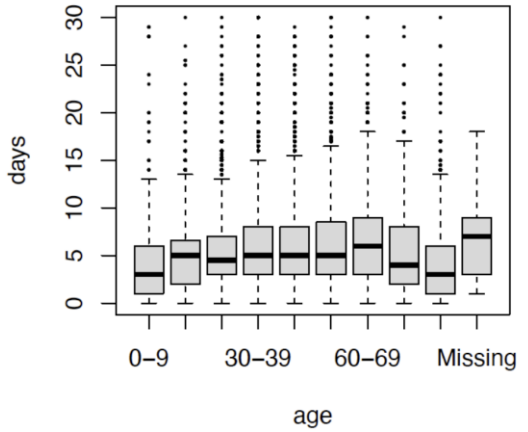


Accessed 8am September 2, 2020
https://www.vdh.virginia.gov/coronavirus/

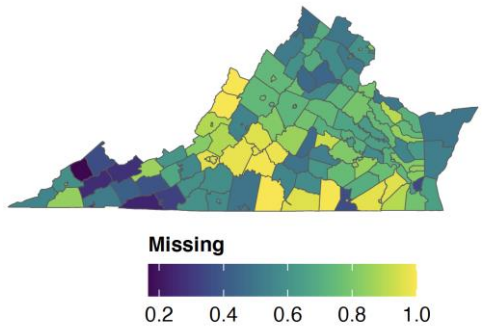
Changes in Case Detection – By District/Age



Slight variations by age group
(0-9, 70-79 and 80-89 have lower medians)
No significant variation by severity (hosp./ICU)



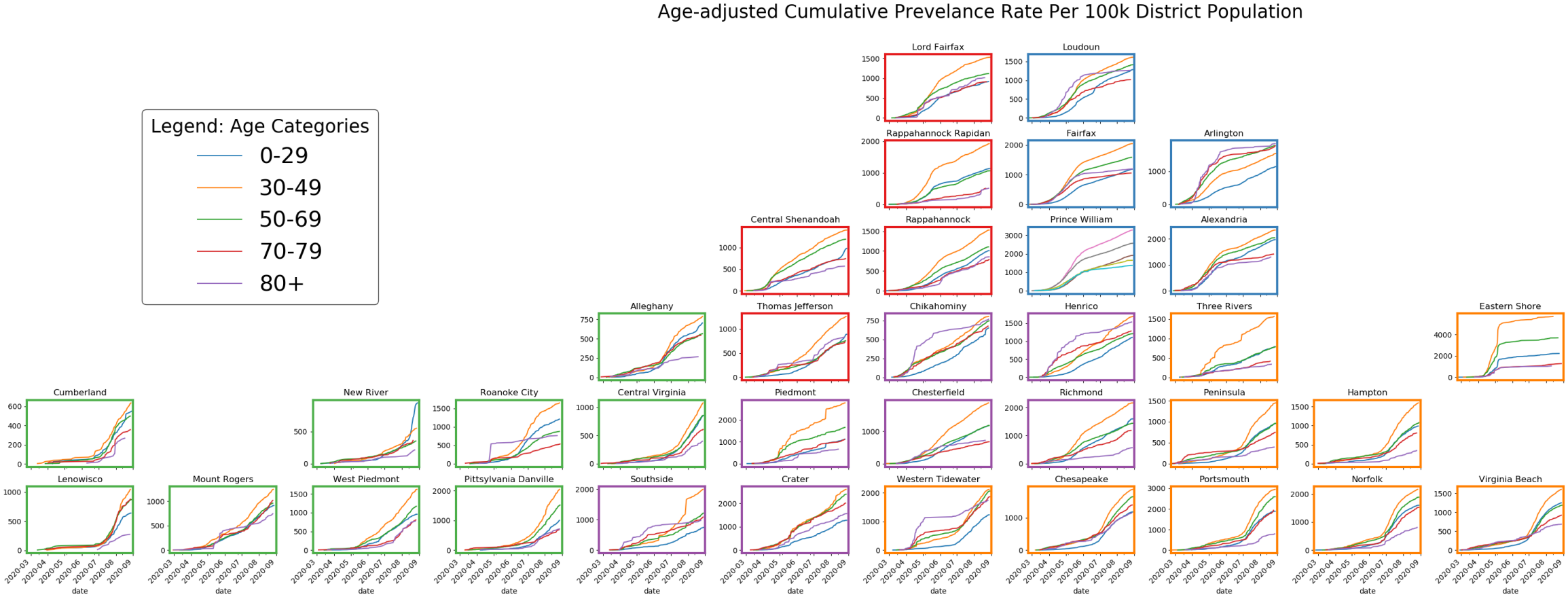
Only ~35% records have entries



Age-Specific Attack Rates (per 100K)

Cumulative Age-specific Attack Rates (per 100k)

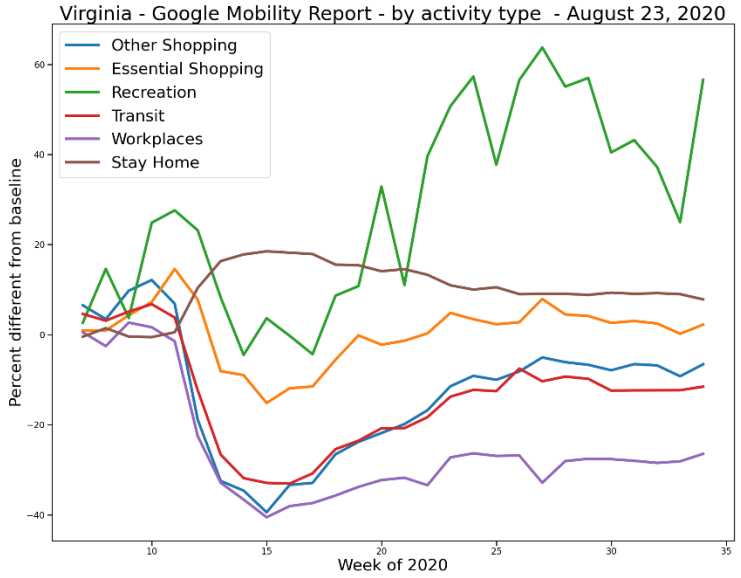
- Younger age groups outpace older in many districts

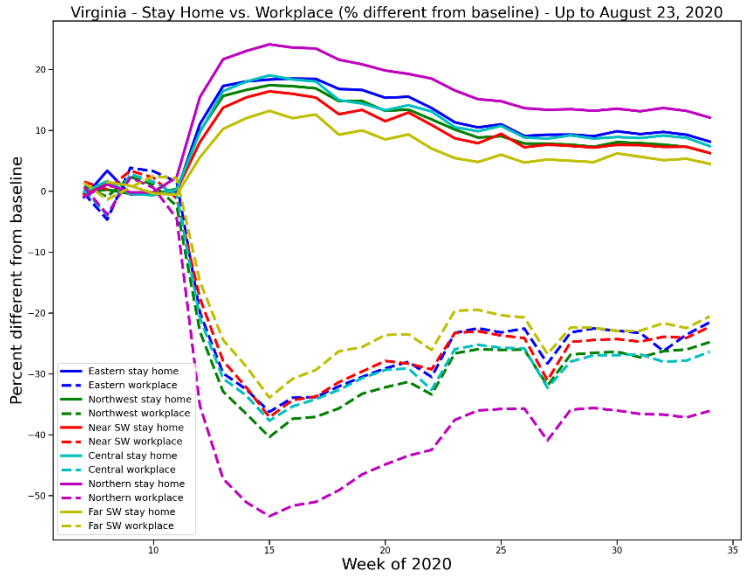


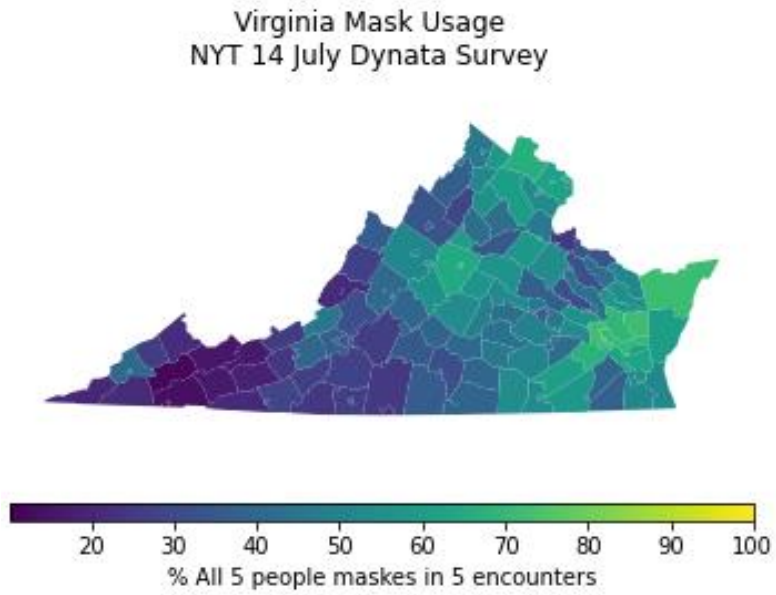
Estimating Effects of Social Distancing

Google Mobility data shows continued slow rebound (as of July 26th)
https://www.google.com/covid19/mobility/

- Continued slow reduction of those staying at home. Workplace levels remain low.
  - Urban/Rural variations in levels (e.g., Northern vs Far SW)
- Essential shopping back to baseline. Other shopping/transit trending towards baseline.
- Parks and recreation significantly higher than baseline (seasonal effects).
- Mask usage not evenly distributed, higher in Northern central, lower Southwest and Richmond area.







District Trajectories – New Surges starting

Hockey stick fit used to describe recent growth patterns

Declining: Sustained decreases following a recent peak

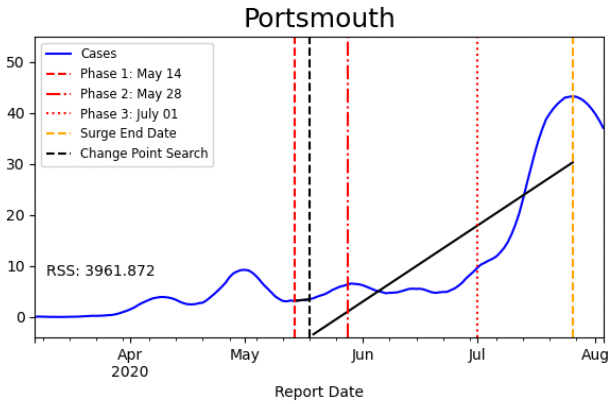
Plateau: Steady level with minimal trend up or down

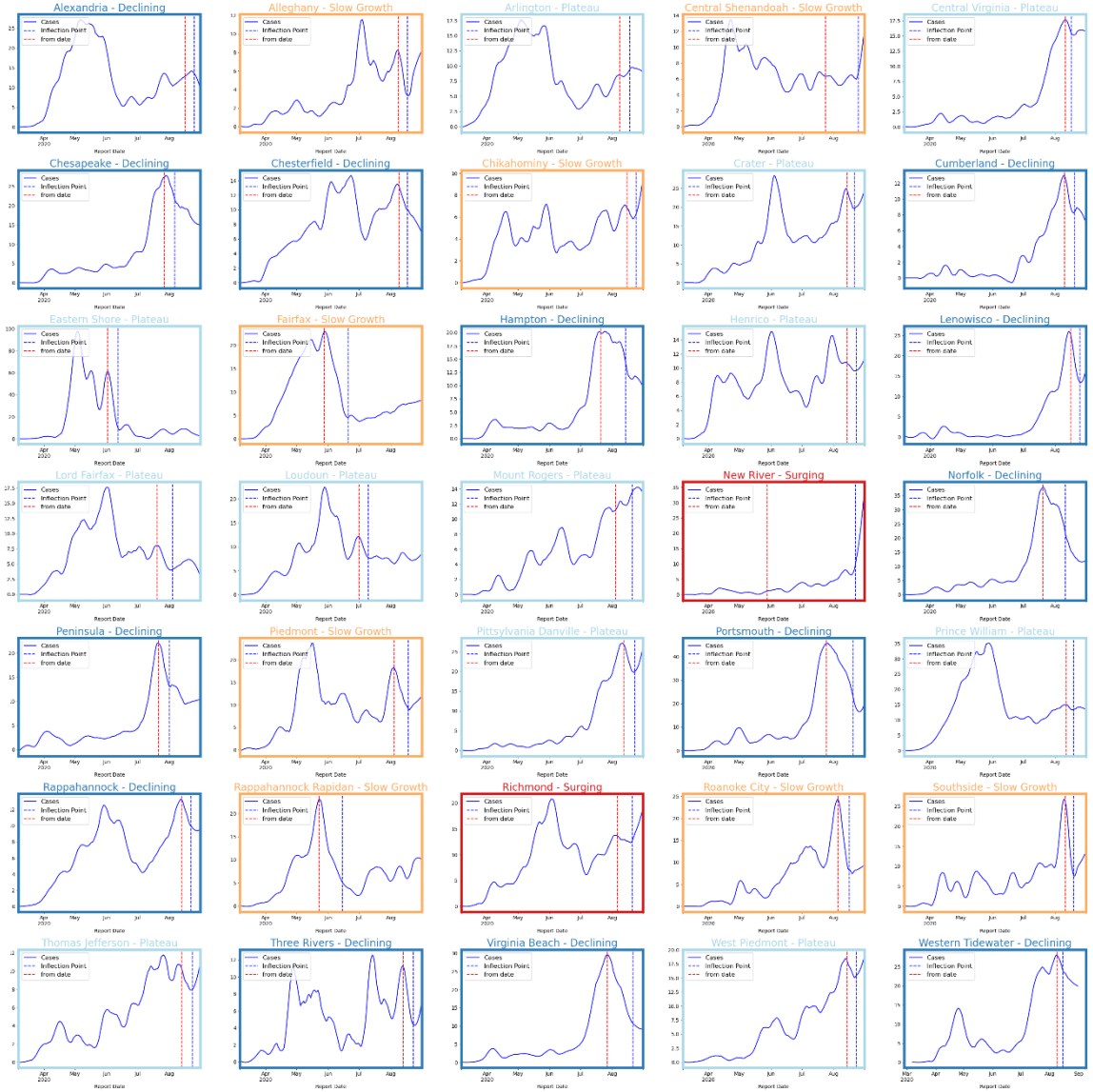
Slow Growth: Sustained growth not rapid enough to be considered a Surge

In Surge: Currently experiencing sustained rapid growth and exceeds recent inflection points

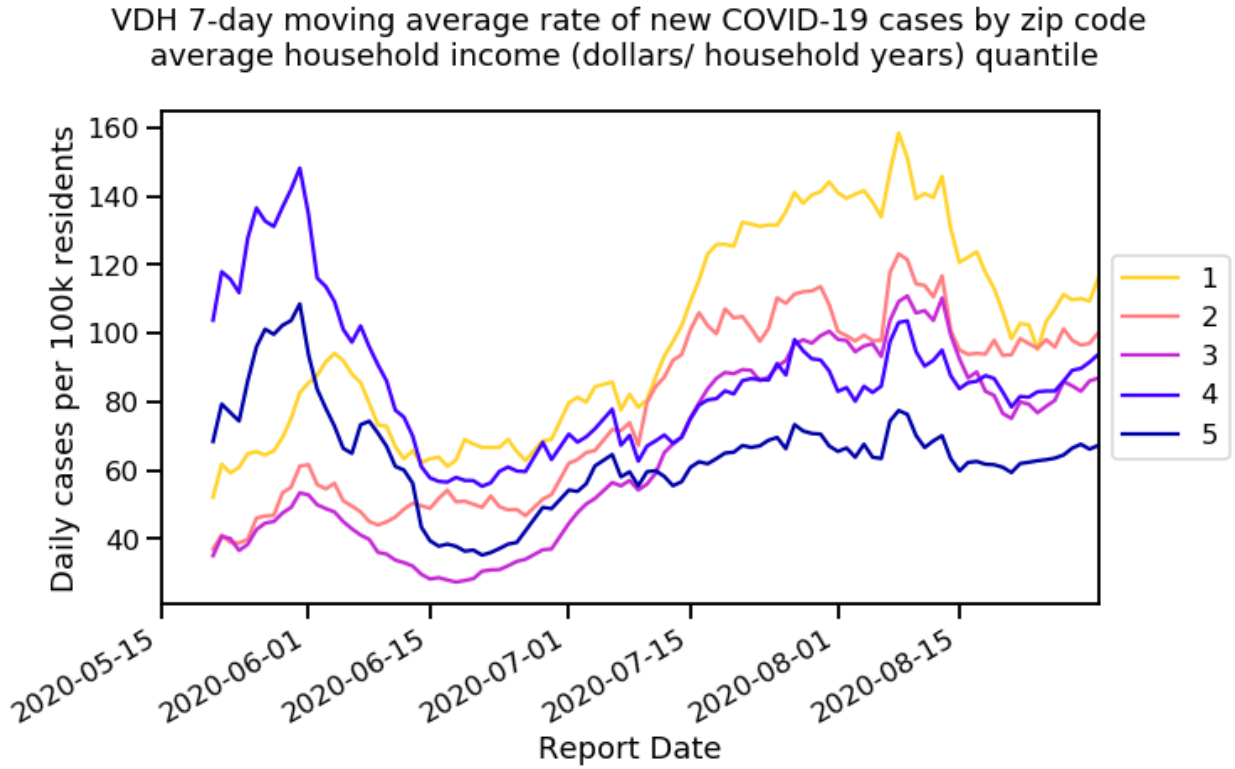
Status	# Districts (last week)
Declining	13 (17)
Plateau	12 (15)
Slow Growth	8 (2)
In Surge	2 (1)

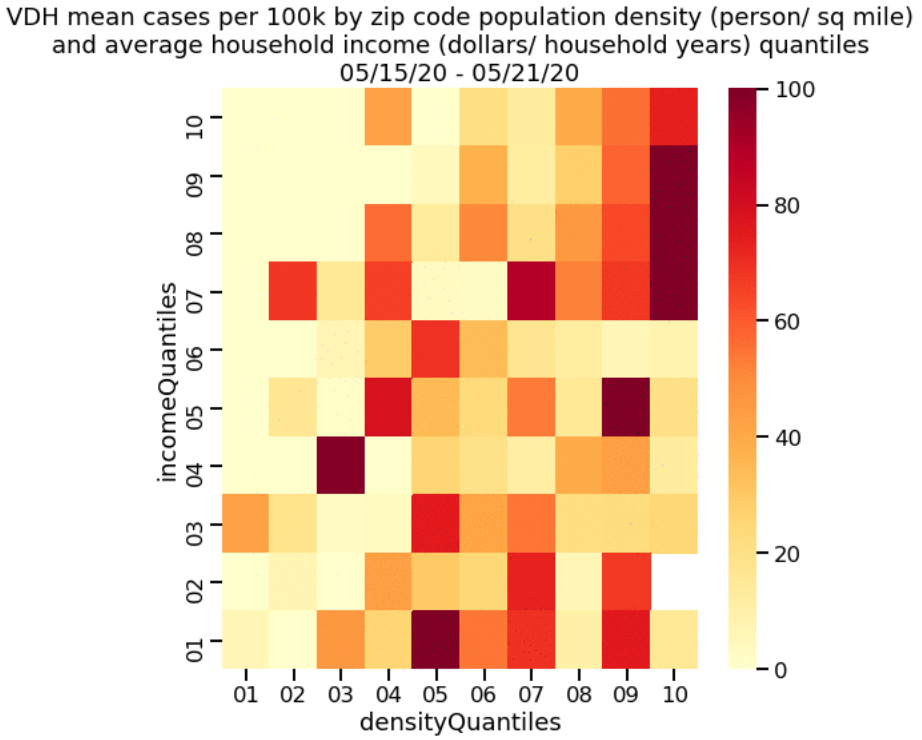
Hockey stick fit





Impact across Density and Income





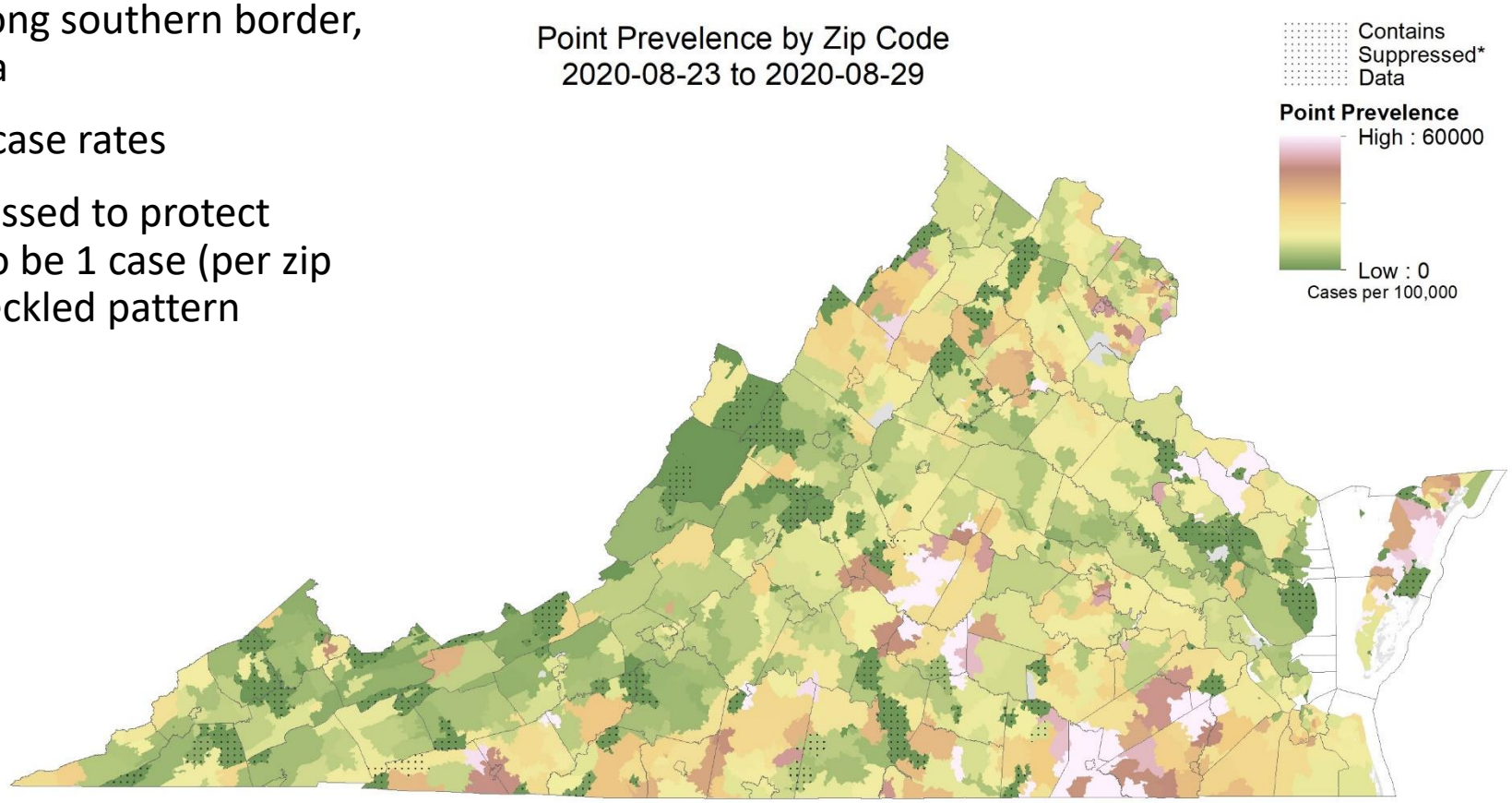
Lower 20% income zip codes still reporting highest case rates

Can see the evolution from denser and wealthier zip codes to poorer and less dense zip codes

Zip-code level weekly Case Rate (per 100K)

Case Rates in the last week by zip-code

- Concentrations of prevalence along southern border, Central VA, and northern Virginia
- Rural populations showing high case rates
- Many counts are low and suppressed to protect anonymity, those are assumed to be 1 case (per zip per day) and shown with the speckled pattern



Model Update – Adaptive Fitting

Adaptive Fitting Approach

Each county fit precisely, with recent trends used for future projection

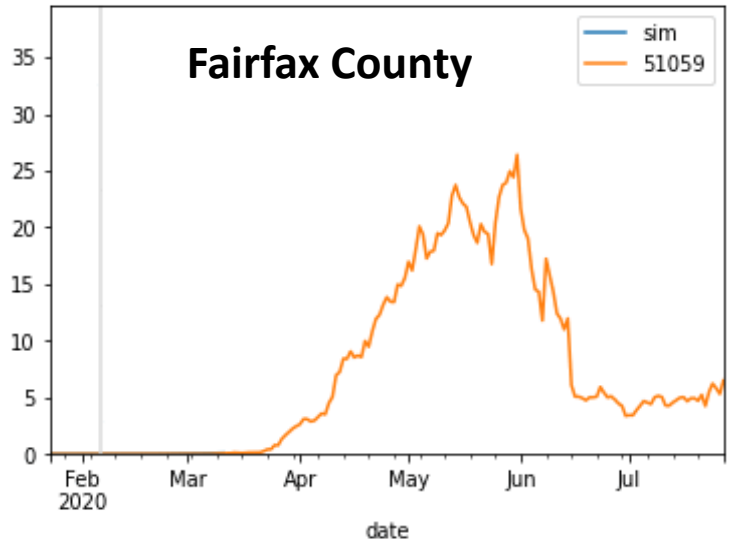
- Allows history to be precisely captured, and used to guide bounds on projections

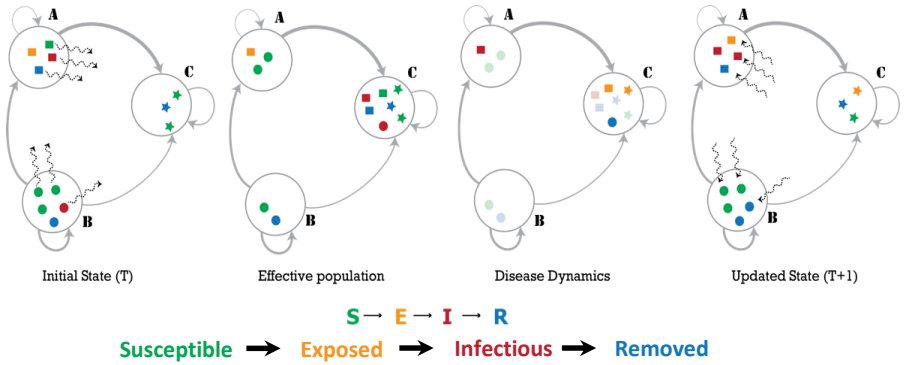
Model: An alternative use of the same meta-population model, PatchSim

- Allows for future "what-if" Scenarios to be layered on top of calibrated model
- Eliminates connectivity between patches, to allow calibration to capture the increasingly unsynchronized epidemic

External Seeding: Steady low-level importation

- Widespread pandemic eliminates sensitivity to initial conditions
- Uses steady 1 case per 10M population per day external seeding





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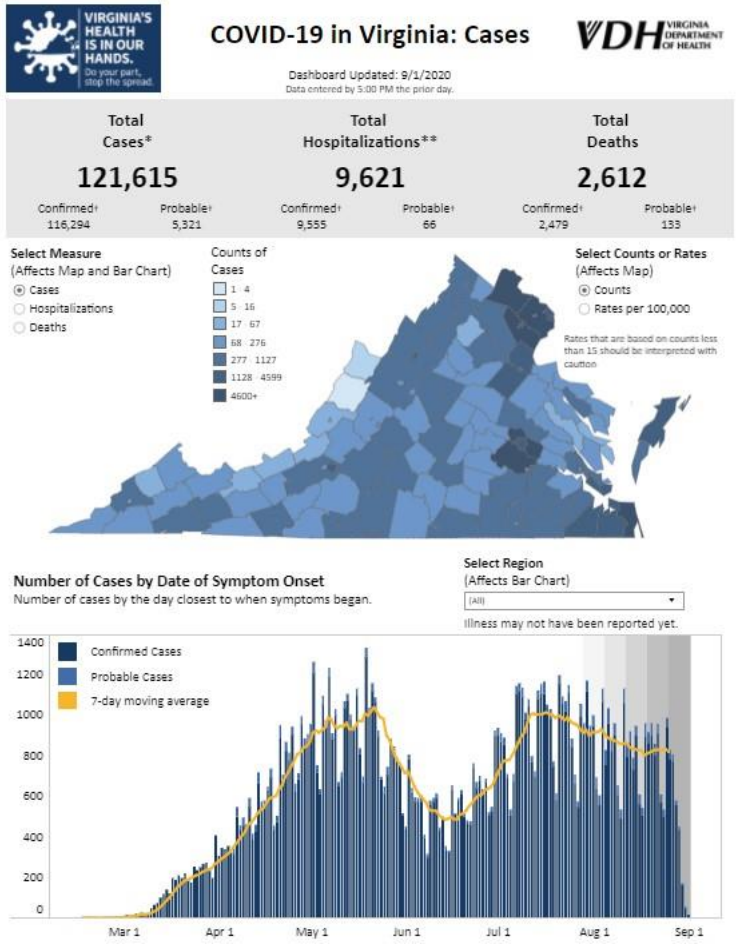
Calibration Approach

- **Data:**
  - County level case counts by date of onset (from VDH)
  - Confirmed cases for model fitting
- **Calibration:** fit model to observed data
  - Tune transmissibility across ranges of:
    - Duration of incubation (5-9 days), infectiousness (3-7 days)
    - Undocumented case rate (2x to 15x)
    - Detection delay: exposure to confirmation (4-12 days)
  - Approach captures uncertainty, but allows model to precisely track the full trajectory of the outbreak
- **Project:** future cases and outcomes using the most recent parameters with constraints learned from the history of the fit parameters
  - Mean trend from last 7 days used, adjusted by variances in the previous 3 weeks
  - 1 week interpolation to smooth transitions in rapidly changing trajectories
  - Particles with high error or variance filtered out



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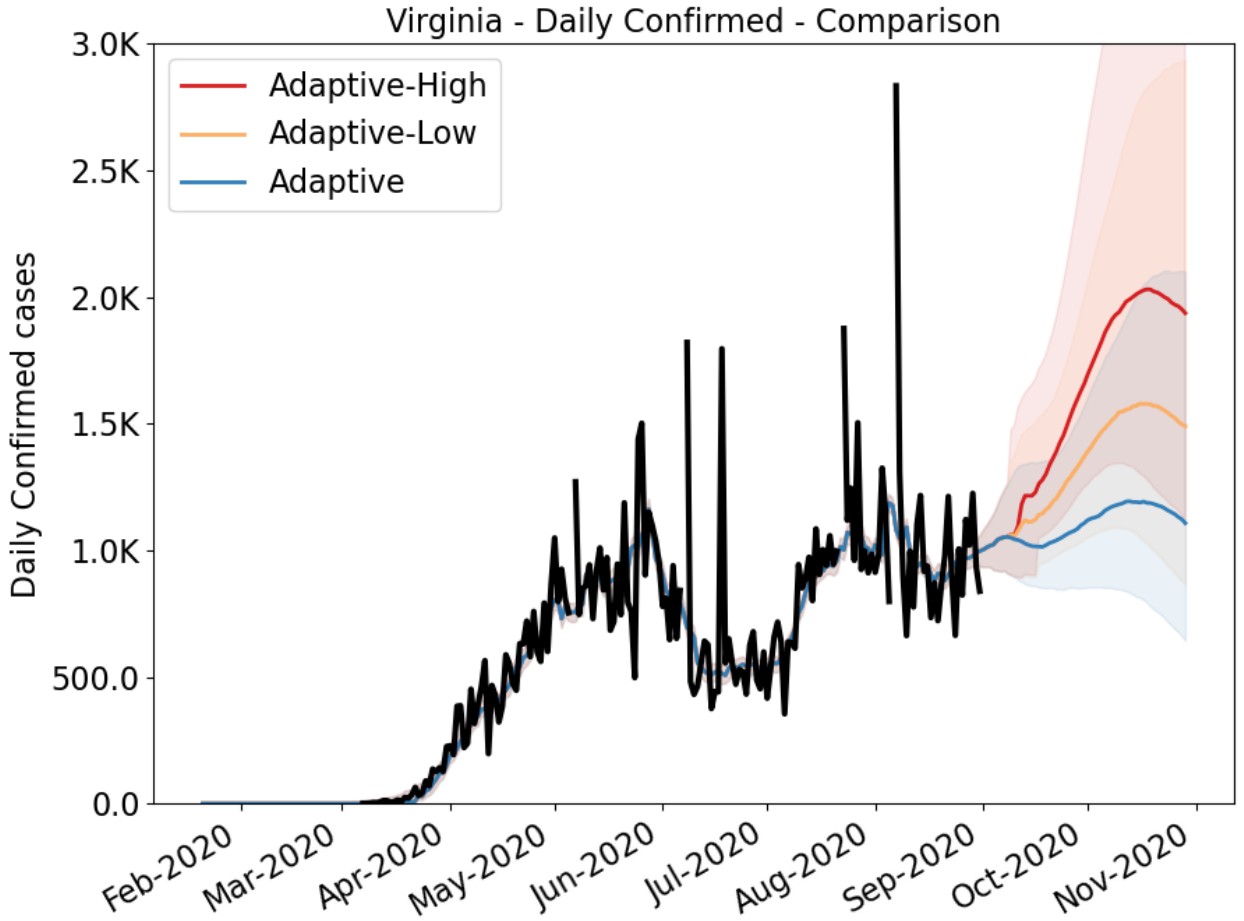
Scenarios – Seasonal Effects

- Societal changes in the coming weeks may lead to an increase in transmission rates
  - Start of in-person school
  - Changes to workplace attendance
  - Seasonal impact of weather patterns
- Three scenarios provided to capture possible trajectories related to these changes starting following Labor Day, Sept 7th, 2020
  - Adaptive: No change from base projection
  - Adaptive-Low: 10% increase in transmission starting Sept 8th, 2020
  - Adaptive-High: 20% increase in transmission starting Sept 8th, 2020

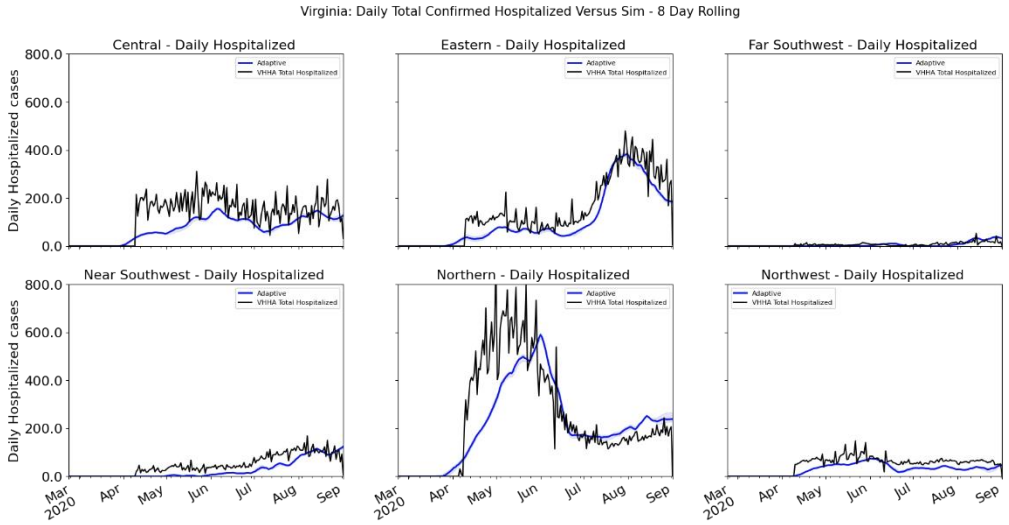
Model Results

Outcome Projections

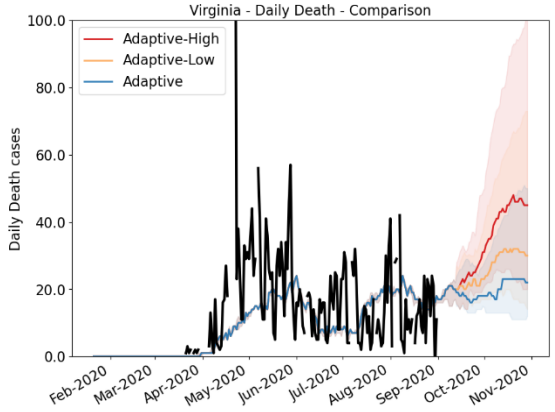
Confirmed cases



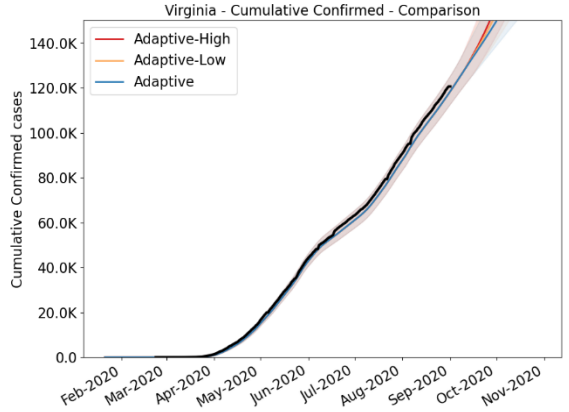
Estimated Hospital Occupancy



Daily Deaths



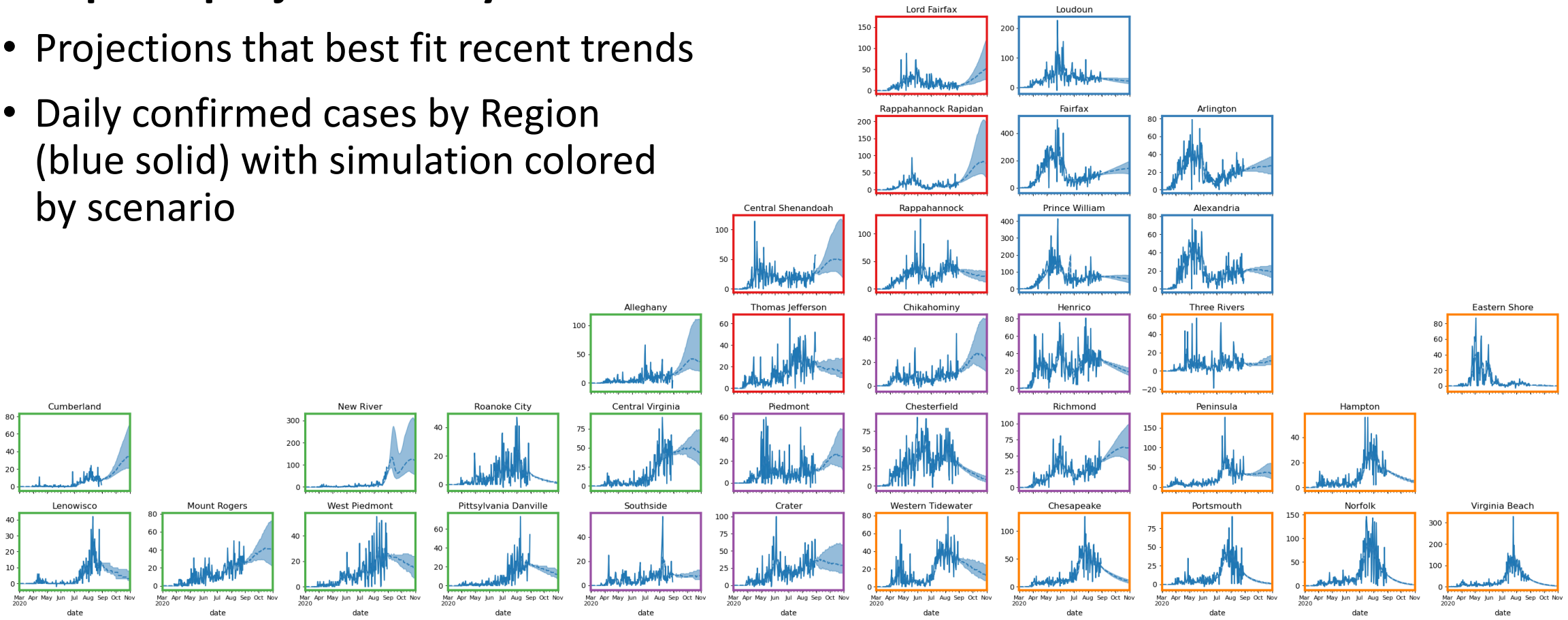
Cumulative Confirmed cases



District Level Projections: Adaptive

Adaptive projections by District

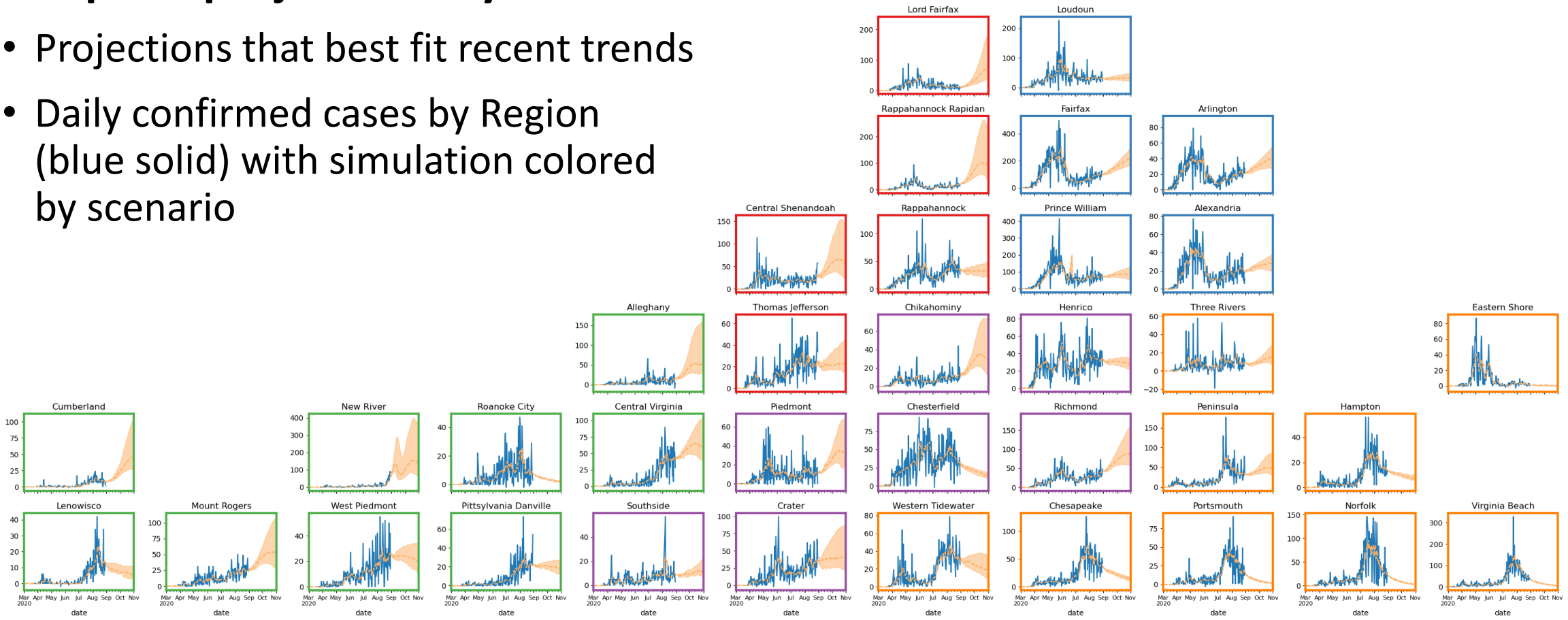
- Projections that best fit recent trends
- Daily confirmed cases by Region (blue solid) with simulation colored by scenario



District Level Projections: Adaptive-Low

Adaptive projections by District

- Projections that best fit recent trends
- Daily confirmed cases by Region (blue solid) with simulation colored by scenario



District Level Projections: Adaptive-High

Adaptive projections by District

- Projections that best fit recent trends
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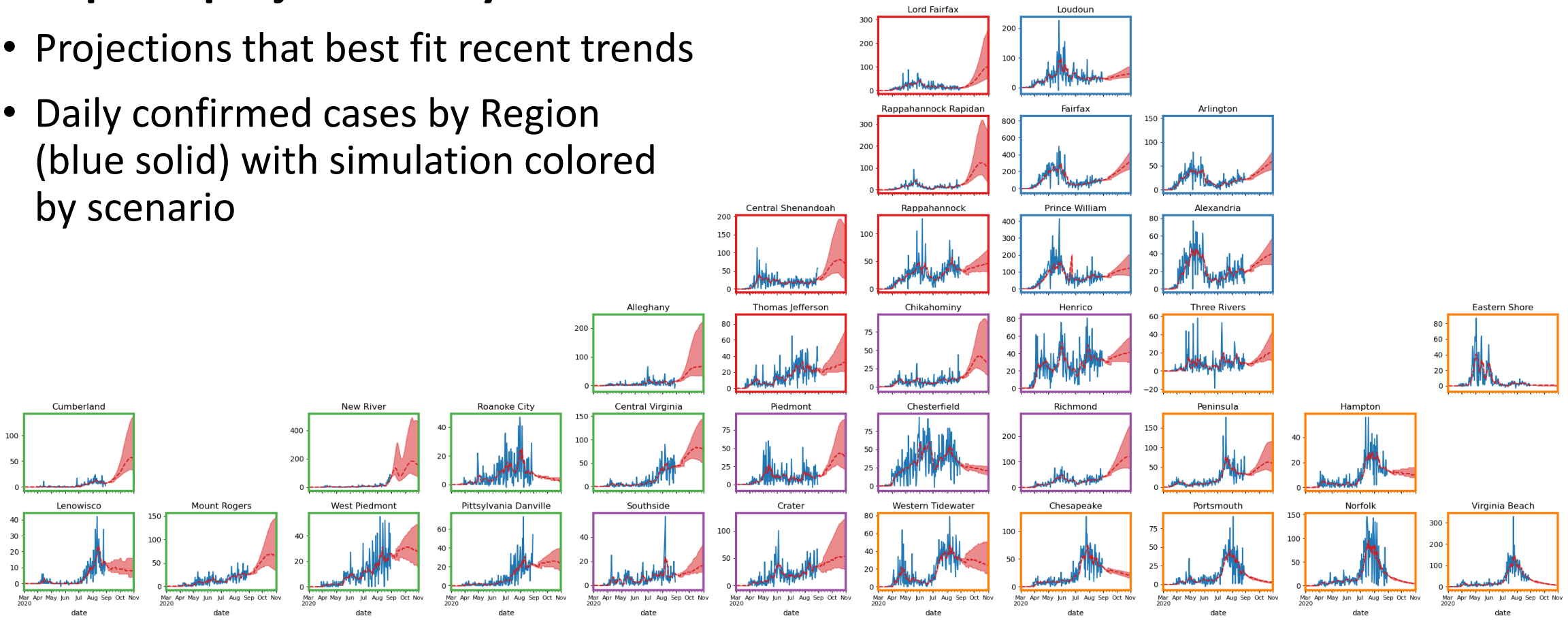
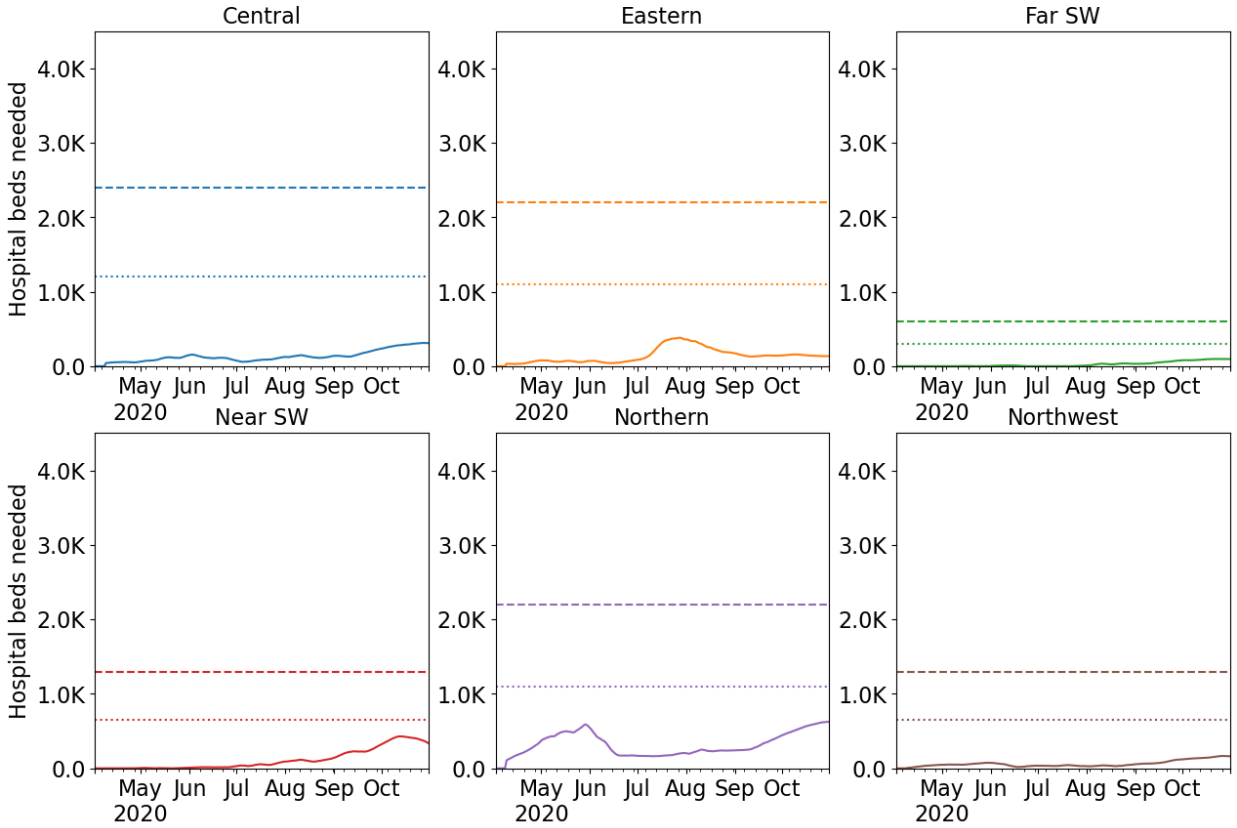


Hospital Demand and Capacity by Region

Capacities by Region – Adaptive-High

COVID-19 capacity ranges from 80% (dots) to 120% (dash) of total beds



Week Ending	Adaptive	Adaptive-High
8/30/20	6,633	6,633
9/6/20	7,018	7,018
9/13/20	7,323	7,411
9/20/20	7,140	8,595
9/27/20	7,283	9,755
10/4/20	7,679	11,394
10/11/20	8,078	12,966
10/18/20	8,319	13,901
10/25/20	8,263	14,131
11/1/20	7,910	13,718
11/8/20	7,341	13,079
11/15/20	6,680	12,376

Based on Adaptive-High scenario

- No regions forecast to exceed capacity

* Assumes average length of stay of 8 days

Key Takeaways

Projecting future cases precisely is impossible and unnecessary.
Even without perfect projections, we can confidently draw conclusions:

- **Mixed trends remain: surges fade as others begin, growth plateaued overall, with high variation across the state. Incidence hovers at national average.**
- Projections are also mixed across a range of slow-growth, plateaus, and declines.
- Recent model updates:
  - Adaptive Fitting projection remains, slight adjustments to projection filtering.
  - Seasonal effects scenarios for planning for end of summer changes.
- The situation is changing rapidly. Models will be updated regularly.

References

Venkatramanan, S., et al. "Optimizing spatial allocation of seasonal influenza vaccine under temporal constraints." *PLoS computational biology* 15.9 (2019): e1007111.

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Cuebiq: COVID-19 Mobility insights. https://www.cuebiq.com/visitation-insights-covid19/

Biocomplexity page for data and other resources related to COVID-19: https://covid19.biocomplexity.virginia.edu/

Questions?

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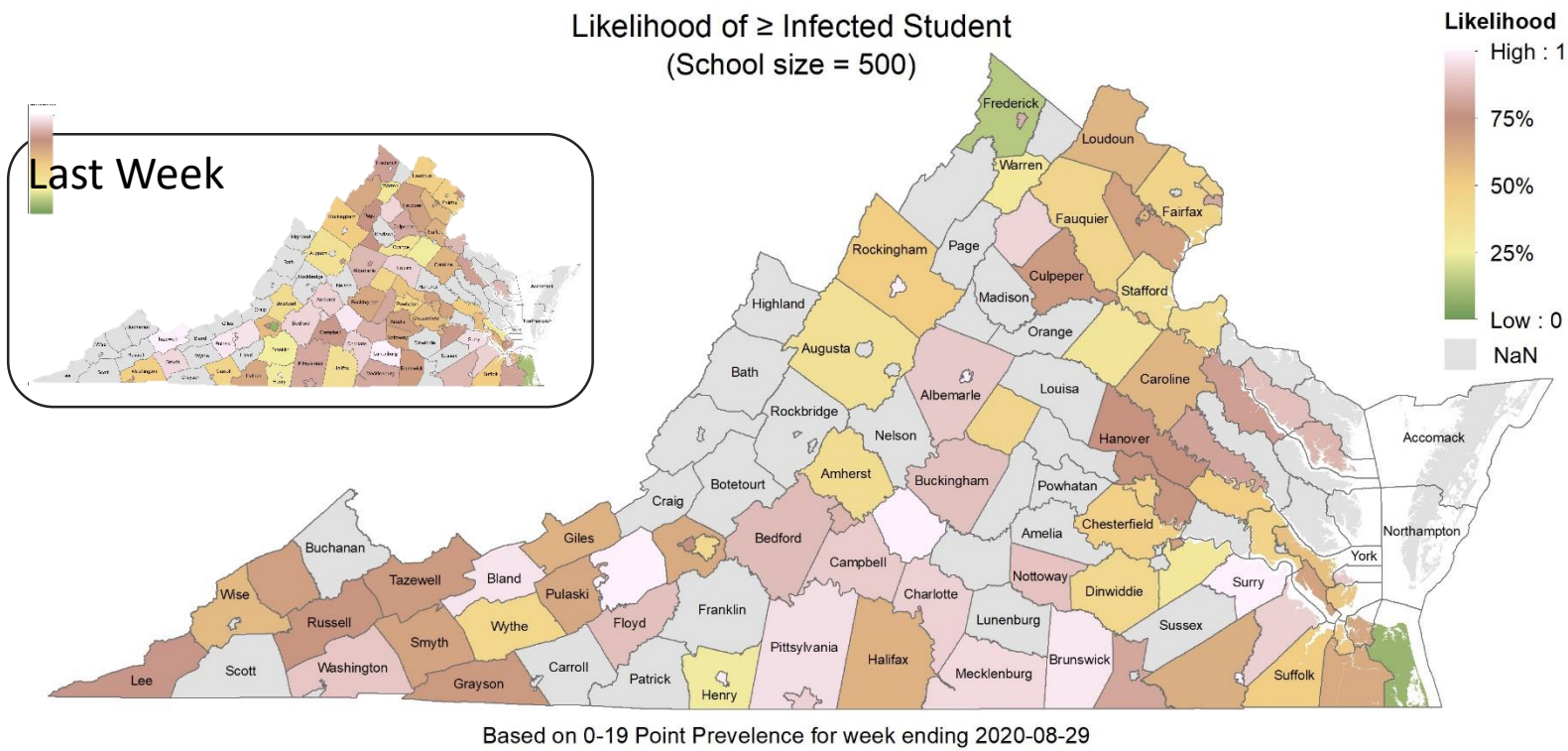
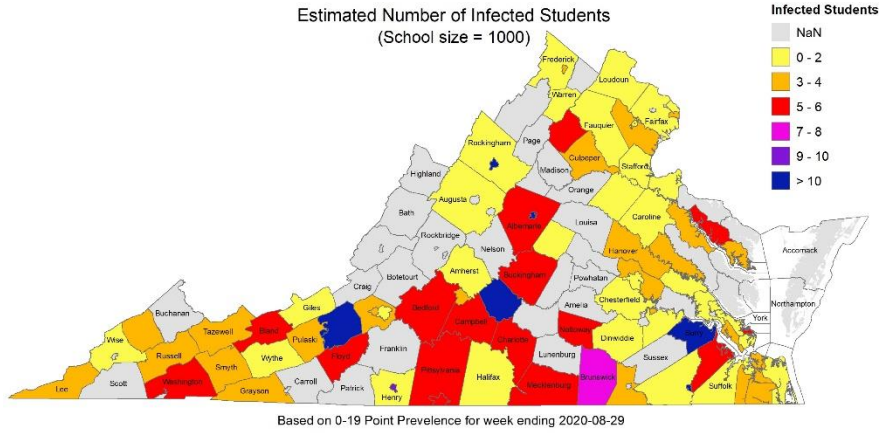
Supplemental Slides

School Age Prevalence

If all schools were open this past week, how many infected students might we expect to be in attendance?



- Based on prevalence during week of August 22nd-29th
- Using school-age incidence in the last week, we estimate the likelihood any collection of school age kids in a school size of 500 will have at least one infection
- Assume that for each confirmed case there are 6 other undetected infections



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Recent Parameter Validation

New York State announced sero-prevalence survey results on May 2nd

- 15,000 antibody tests conducted randomly through the state at grocery stores
- **Total Attack Rate**: 12.3%

Estimation of undetected infections

- Total infections in NY = 2.46M, total of 300K confirmed cases
- Confirmed case detection = 12% of infections (close to 15% used in model)

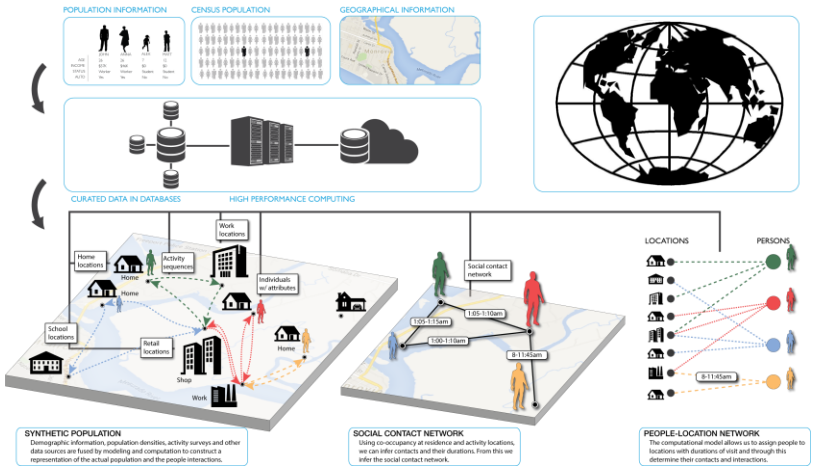
Estimation of hospitalizations from infections

- Total infections in NY = 2.46M, total of 66K hospitalizations
- Hospitalizations = 2.7% of infections (close to 2.25% used in model)

Agent-based Model (ABM)

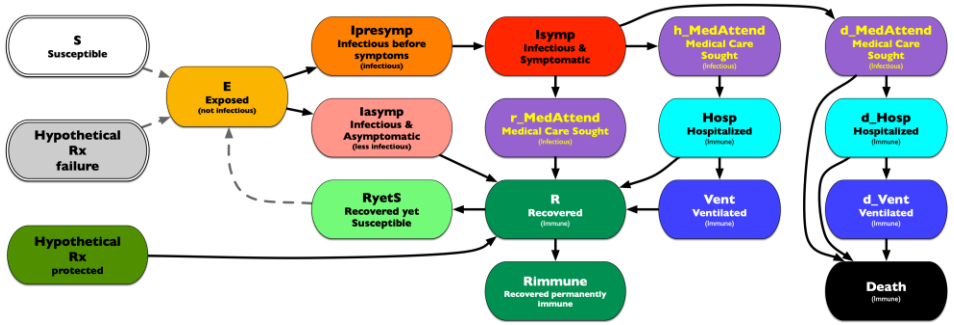
EpiHiper: Distributed network-based stochastic disease transmission simulations

- Assess the impact on transmission under different conditions
- Assess the impacts of contact tracing



Synthetic Population

- Census derived age and household structure
- Time-Use survey driven activities at appropriate locations



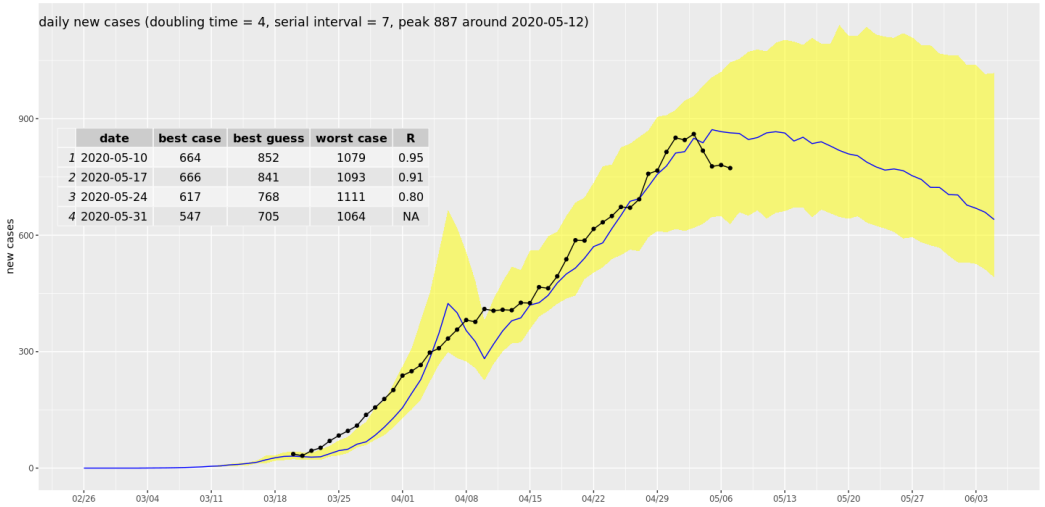
Detailed Disease Course of COVID-19

- Literature based probabilities of outcomes with appropriate delays
- Varying levels of infectiousness
- Hypothetical treatments for future developments

ABM Social Distancing Rebound Study Design

Study of ”Stay Home” policy adherence

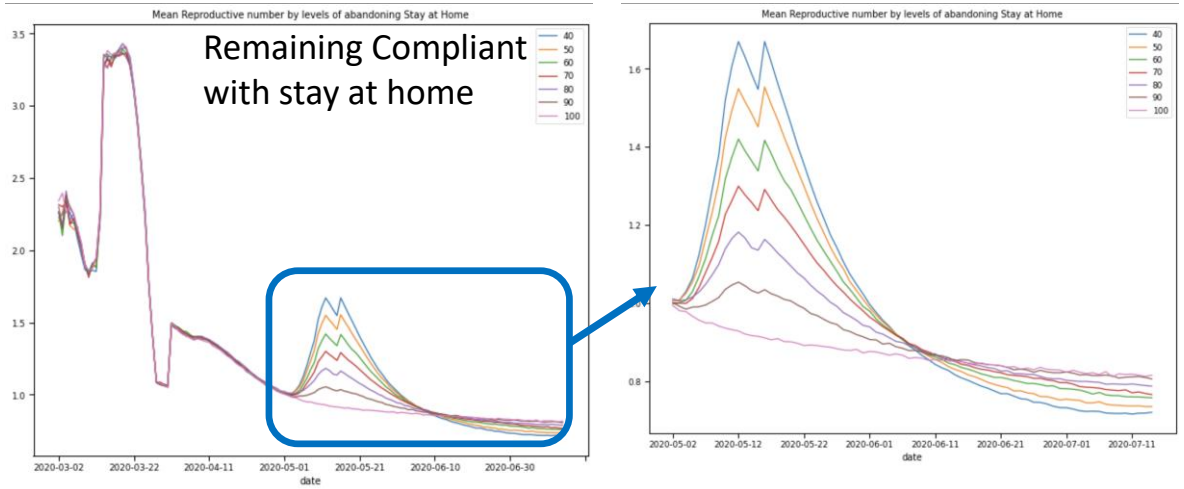
- Calibration to current state in epidemic
- Implement “release” of different proportions of people from ”staying at home”



	date	best case	best guess	worst case	R
1	2020-05-10	664	852	1079	0.95
2	2020-05-17	666	841	1093	0.91
3	2020-05-24	617	768	1111	0.80
4	2020-05-31	547	705	1064	NA

Calibration to Current State

- Adjust transmission and adherence to current policies to current observations
- For Virginia, with same seeding approach as PatchSim

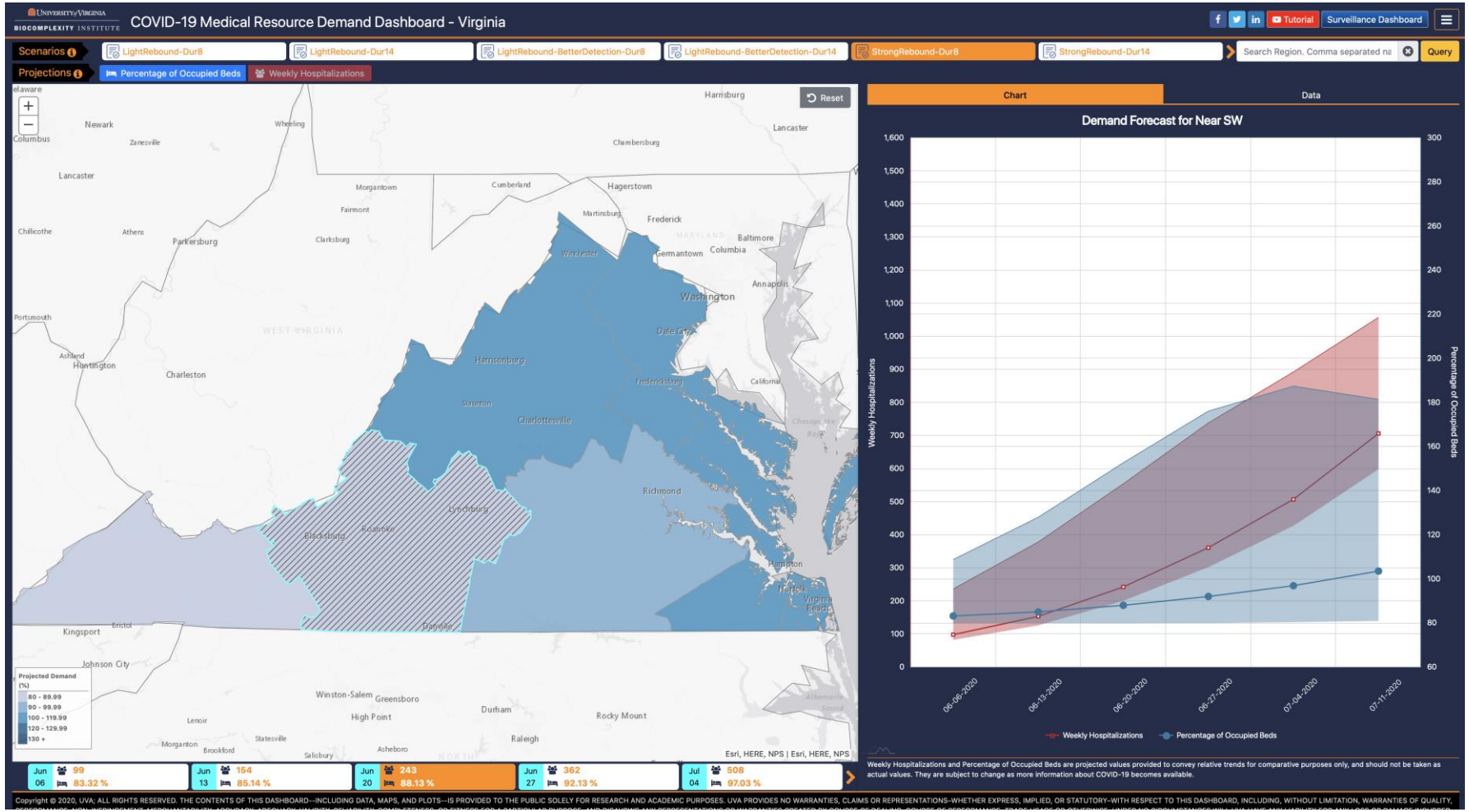


Impacts on Reproductive number with release

- After release, spike in transmission driven by additional interactions at work, retail, and other
- At 25% release (70-80% remain compliant)
- Translates to 15% increase in transmission, which represents a 1/6th return to pre-pandemic levels

Medical Resource Demand Dashboard

https://nssac.bii.virginia.edu/covid-19/vmrddash/



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